

# ON A TIME VARIATION OF NEUTRINO'S MASS

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## Abstract

After the introduction to the subject, we review the Machian relations involving the different kinds of energy densities in the Universe. By suposing that dark-matter is composed by Neutrino's massive energy, we hint that the Neutrino's masses should be proportional to  $R^{-1}$ , while the total number of Neutrinos in the Universe increases with  $R^2$ , where  $R$  stands for Hubble's length. This makes possible that the dark mater-energy density be of Neutrinos origin, to vary with  $R^{-2}$ , as is necessary for a Machian Universe. The neutrino average mass is estimated for the present Universe ( $=10^{-76}$ g).

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## I - INTRODUCTION

The subject of mass-varying neutrinos, has been very recently given attention[22][23][24]. But, first, let us make an historical review of the neutrino research.

In 1930 the Austrian theoretical physicist Wolfgang Pauli, Nobel Prize due to his research on the electron spin, verified in the processes of electron emission from neutrons, that the energy-momentum balance was violated. In other terms: the much solid principle of energy-momentum conservation of special relativity seemed to loose its preeminence at the basis of every physical theory. Well something highly perplexing, for in spite of being universally applied to all known high energy processes, it could not be corroborated in this special process of electron emission from neutrons, the so called Beta emission process. A painful problem of course, but brilliantly solved through Pauli's revolutionary hypothesis and Enrico Fermi's theory, in 1934, [2]. Pauli postulated the existence of a new particle, the neutrino[1] that was responsible for the disappearance of energy-momentum in the neutron decay (beta emission). Fermi forwarded the neutrino theory wherein it is deduced that this new postulated neutral particle has a probability of interaction with other particles, 10 to power 22 times smaller than what was known then. Therefore the neutrino acted as if a phantom particle that could not be easily detected. Only in 1953, twenty years after Fermi's theory, was the particle to emerge to existence, thanks to the experiments done by two American experimental physicists, Frederick Reines and Clyde Cowan. They used then a new detection technique that afforded the possibility for detection of an effect predicted by Fermi. It was the technique based on a different type of particle detector, the scintillation counter. Being faithful to a fundamental physical principle, the energy-momentum conservation, Pauli and Fermi were responsible for one of the most important scientific discovery of the XXth century. Fermi's predictions from his theory were widely verified by the community of high-energy physicists, such that nobody doubted the existence of the putative neutrino. Frederick Reines who received the Nobel Prize in 1995 made the following important epistemological comment:

“It must be recognized, however, that independent of the observation of a ‘free neutrino’ interaction with matter, the Fermi theory was so attractive in its explanation of beta decay that belief in the neutrino as a ‘real’ entity was general”.[1]

Reines’ comment is a remarkable epistemological judgement in so far as to view certain experimental evidence of a theory, not something clinching or crucial. Fermi’s theory offered a galaxy of effects in high-energy physics of so important level, that the putative neutrino could be kept as such for 20 years without bothering physicists. Reines and Cowan’s discovery of the free neutrino was not a crucial test of a theory, but an experimental success after a history of theoretical and other experimental evidences. We are going to deal afterwards on the question of clinching experimental proofs. An analogous situation we are going to point out in the history of the heliocentric theory, accepted by every astronomer of the XVIIth century without the “clinching proof” of stellar parallax obtained by Bessel on the XIXth century. Let us remind that Enrico Fermi’s theory of 1934 is considered the birth of quantum field theory[2], which is cornerstone in elementary particles theory. Fermi received the Nobel in 1938.

The present theory of material reality’s offers three families of elementary particles:

- a) 6 quarks and 6 antiquarks.
- b) Leptons and antileptons: electron, muon, tau-particle, neutrino-e, neutrino-mu and neutrino-tau.
- c) Gauge bosons: photon,  $W^+$ ,  $W^-$ ,  $Z$ , and Gluon. Being bosons they have no antiparticles’ counterpart.

Let us add some considerations as to the three neutrinos. The neutrino developed in Fermi’s theory and detected by Reines and Cowan was called by Feinberg in 1958, neutrino-e, since it was related to the beta decay of the neutron. Besides Feinberg predicted that the neutrino generated by the muon decay should be different and it was then named neutrino-mu. Through an experiment done in 1962 by Leon Lederman, Schwartz, and Steinberger, the prediction was brilliantly corroborated[3]. In 21/7/2000 a group of 54 American, Japanese, Korean, and Greek physicists at Fermilab, announced the detection of the neutrino-tau.[4] The neutrino-tau results from the decay of the lepton tau particle. Thus, from 1953 to 2000 the 3 neutrinos predicted in the theoretical structure had been detected.

From 1967 to 1998 several experiments were done in order to measure the neutrino flux produced in the Sun. As we know the thermonuclear reactions inside our star, would produce

abundant torrents of neutrinos-e. The first measurements done in 1967 by Ray Davies offered a perplexing result: the flux measured had been about 1/3 of the predicted value[5][6]. In 1969 the Italian physicist Pontecorvo suggested a hypothesis that would account for the missing Solar neutrinos: en route to Earth part of them would oscillate to a different type of neutrinos. This hypothesis was endorsed in 1985 by two Russian physicists Miteyev and Smirnov: from the Sun to Earth a substantial part of neutrinos-e would transform into neutrinos-mu or tau[7].

According to the standard model of elementary particles theory, the property of oscillation of a neutrino into another type presupposes the existence of mass. Hence the old assumption of the massless neutrino should be disposed off. A team of 300 American and Japanese physicists at Takayma proceeded to an experiment with the huge detector Super-Kamiokande in order to detect oscillation of neutrino-mu into neutrino-tau in the flux of secondary cosmic rays. In spite of the cautious language of Yoshiro Suzuki of the University of Tokyo, the results strongly favour the oscillation of neutrinos-mu[8]. These findings with the Super-Kamiokande are regarded as compelling but not definitive[9]. More recently, Tsuyoshi Nakaya of Kyoto University announced in June, 2004 at a meeting in Paris, a reassuring confirmation of the oscillation mechanism, that is: strong evidence of oscillation of neutrino-mu into neutrino tau[10]. The square masses of the neutrino eigenstates were measured from the Super-Kamiokande data and were in agreement with the oscillation parameters from atmospheric data.

Notwithstanding the successes obtained, new theoretical problems are being tackled in the domain of the physics of neutrinos[11]. Well there is no end in the quest for knowledge and understanding of reality: problems solved open the doors for new problems.

## II MACHIAN RELATIONS FOR DARK MATTER ENERGY

It has been asserted, that 67% of the energy density of the Universe, is due to a cosmological "constant" energy. The restant energy density is fractioned in two parts: 5% as visible mass and 28% as dark matter. Let us suppose that dark matter is constituted by neutrinos with non-zero rest mass. Berman[12][13][14] has suggested that, if Mach's principle is understood as meaning that the total energy of the Universe is null, and if each particular energy contribution to the total energy density, has constant participation during the whole

history of the Universe, one may obtain different Machian relations. These Machian relations, of which, the Brans-Dicke [15] relation is a particular case, should not, according to Berman, be viewed as just coincidental with the present Universe. Suppose that the total energy is given by:

$$E = Mc^2 - \frac{GM^2}{2R} + 4\pi\Lambda\frac{R^3}{3\kappa} + \frac{L^2}{MR^2} \quad , \quad (1)$$

where the four terms to the right of relation (1) represent respectively the inertial, gravitational, cosmological constant's and rotational energies.

When we impose,

$$E = 0 \quad , \quad (2)$$

we obtain:

$$\frac{GM}{2c^2R} - \frac{4\pi}{3\kappa} \left[ \frac{\Lambda R^3}{c^2M} \right] - \frac{L^2}{c^2M^2R^2} = 1 \quad . \quad (3)$$

If no one of the above terms will increase or decrease different than the others, we can solve equation (3) by imposing that:

$$\frac{GM}{2c^2R} = \gamma_1 \quad , \quad (4)$$

$$\frac{4\pi}{3\kappa} \left[ \frac{\Lambda R^3}{c^2M} \right] = \gamma_2 \quad , \quad (5)$$

$$\frac{L^2}{c^2M^2R^2} = \gamma_3 \quad , \quad (6)$$

where the  $\gamma$ 's obey the conditions:

$$1) \quad \gamma_i = \text{constant} \quad (i = 1, 2, 3) \quad , \quad (7)$$

$$2) \quad \gamma_1 - \gamma_2 - \gamma_3 = 1 \quad . \quad (8)$$

It can be checked that, due to the original Brans-Dicke relation [15],

$$\frac{GM}{c^2R} \cong 1 \quad , \quad (9)$$

and also because of the above arguments, all the  $\gamma$ 's have a near unity value. We thus obtain, with Berman[14], the following variation laws:

$$M \propto R \quad ; \quad (10)$$

$$L \propto R^2 \quad ; \quad (11)$$

$$\Lambda \propto R^{-2} \quad . \quad (12)$$

The Machian relations (4)(5)(6) have been noticed long ago, as approximate relations for the present Universe; the radical departure made by Berman, is contained in the fact that the  $\gamma$ 's are constant during the lifespan of the Universe, and not only for the present time, so that relations (10)(11)(12), are valid during all times.

We now can obtain the corresponding energy densities for the above relations:

$$\rho_1 = \frac{M}{\frac{4}{3}\pi R^3} = \left[ \frac{6\gamma_1 c^2}{4\pi G} \right] R^{-2} \quad , \quad (13)$$

$$\rho_2 = \frac{\Lambda}{\kappa} = \left[ \frac{\gamma_2 \gamma_1 c^4}{2\pi G} \right] R^{-2} \quad , \quad (14)$$

and,

$$\rho_3 = \frac{\left[ \frac{L^2}{MR^2} \right]}{\frac{4}{3}\pi R^3} = \left[ \frac{3\gamma_1 \gamma_3 c^4}{2\pi G} \right] R^{-2} \quad . \quad (15)$$

We can check that all energy densities are proportional to  $R^{-2}$ , so that, we can also write:

$$\rho_{TOT} = \rho_1 + \rho_2 + \rho_3 = \Gamma R^{-2} \quad ( \Gamma = \text{constant} ) \quad . \quad (16)$$

In the spirit of inflationary Cosmology [16], we identify, for the present Universe,  $\rho_{TOT}$  with the critical density, so that we would have:

$$\rho_{TOT} \cong 2 \times 10^{-29} \text{ g / cm}^3 \quad .$$

In the next Section, we calculate an estimate for neutrinos mass, and its time variation. But, we observe that, if dark matter is a fraction of  $\rho_{TOT}$ , this fraction will also depend on  $R^{-2}$ , so as to keep all relative components equally balanced along time.

### III A theory for neutrinos energy density

As we have noticed before the energy density of dark matter, to be identified with neutrinos, shall be given by:

$$\rho_\nu = 0.27\rho_{TOT} \quad . \quad (17)$$

Berman [17] along with others (see Sabbata and Sivaran, 1994 [21]) have estimated that the Universe possess a magnetic field which, for Planck's Universe, was as huge as  $10^{55}$  Gauss. The relic magnetic field of the present Universe is estimated in  $10^{-6}$  Gauss. We can then, suppose that all neutrinos' spins have been alligned with the magnetic field. On the other hand, the spin of the Universe is believed to have increased in accordance with Machian relation (6) above, which entails relation (11) above. If we call  $n$  the number of neutrinos in the present Universe, and  $n_{Pl}$  its value for Planck's Universe, we may write:

$$\frac{n}{n_{Pl}} = \frac{L}{L_{Pl}} = 10^{120} \quad . \quad (18)$$

Then,

$$n = n_{Pl} \left[ \frac{R}{R_{Pl}} \right]^2 \quad . \quad (19)$$

We have just obtained the relation for the increase of the number of neutrinos with  $R^2$

Now, we write the energy density of neutrinos,

$$\rho_\nu \cong \frac{nm_\nu}{\frac{4}{3}\pi R^3} \quad , \quad (20)$$

where  $m_\nu$  is the rest mass of the average neutrino.

If we impose relation (17) and simultaneously, relations (16) and (20), we conclude two things:

$$1^{st}.) \quad \rho_\nu = 0.27\rho_{Pl} \left[ \frac{R}{R_{Pl}} \right]^{-2} \quad . \quad (21)$$

$$2^{nd}.) \quad m_\nu = \frac{\rho_{Pl} R_{Pl}^4}{R} \quad . \quad (22)$$

We see now that while the number of neutrinos in the Universe increases with  $R^2$ , the rest mass decreases with  $R^{-1}$ ; we may obtain, with  $R \cong 10^{28}$  cm, that the rest mass of neutrinos should be, in the present Universe:

$$m_\nu \cong 10^{-76} \text{ g} \quad . \quad (23)$$

One of us (F.M. Gomide, [25]), has estimated the mass of neutrinos a long time ago, finding, in a seminal paper, the value,  $10^{-65}$  g. Gomide[25] in fact has equated  $m_\nu c^2$  with the self-gravitational energy of the proton. If one equates the self-gravitational energy of the electron, with  $m_\nu c^2$ , with  $R$  as the electron Compton radius, we would find  $10^{-72}$  g.

## IV Conclusions

A law of variation for the number of neutrinos in the Universe has been found. A law of variation for the rest mass of neutrinos was also found.

We remind the reader that Kaluza-Klein's cosmology [18][19], consider time varying rest masses, in a penta-dimensional space-time-matter, of which the fifth coordinate is rest mass. The above results can not be rejected, for the time being, by any known data. We point out, that some of the features of the present calculation, are originated from a seminal paper by Sabbata and Gasperini [20].

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